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Effects of Stretching on Jumping Performance

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Effects of Stretching on Jumping Performance

A Thesis

Presented to

The Faculty of the Department of Physical Education and Recreation Administration
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment

Of the Requirement for the Degree
Master of Science in Physical Education

By

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Effects of Stretching on Jumping Performance

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EFFECTS OF STRETCHING ON JUMPING PERFORMANCE

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August 2005

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Stretching has been a part of warm-up for a very long time. Some recent research has shown that stretching could possibly hinder performance and others have shown it enhances performance. The purpose of this study was to examine whether stretching has an effect on vertical jump, and if so, how long the effects last. Twenty Western Kentucky students (10 M and 10 F) performed three trials each. There was a non-stretching group, a pre-stretching group and a between-stretching group; each of the subjects performed all three. The stretching protocol included a static stretching routine of the gluteus maximus, hamstrings, quadriceps, and triceps surae. This stretching protocol lasted 7 minutes. The non-stretching group did not stretch, they performed two jump tests; the pre-stretching group stretched first and then performed the two jump tests; and the between-stretching group did the first jump test, stretched and performed the final jump test. Subjects were randomly selected for order of performance in each trial. Results showed a significant difference ($p < 0.05$) in pre-stretching group reaction time 1 versus reaction time 2 ($p = 0.035$) and a significant difference in the between-stretching group jump height 1 versus jump height 2 ($p = 0.004$). There were no other significant differences. This suggests that stretching hinders reaction time and the height of a vertical jump.

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Chapter One

Introduction

Stretching has been a part of warm-up and cool-down routines for many years. Coaches, as well as the general population, believe that stretching could be used to enhance their performance. Recent studies have demonstrated decreased performance in some cases. Thus there is a controversy as to whether stretching is advantageous or detrimental to performance. More research is necessary to determine the effects on an athlete's performance.

Statement of the Problem

The purpose of this study was to examine whether stretching had effects on vertical jump and, if so, how long the effects lasted. The independent variable is the designated stretching routine and the dependent variables are the vertical jump performance variables.

Hypothesis

It is hypothesized that vertical jump variables will be negatively acutely affected by a static stretching routine.

Significance of the Study

Previous stretching studies showed that stretching had a negative effect on performance while others showed that stretching had no effect. These studies used

countermovement jumps, drop jumps and how stretching affects single jumps. This particular study examines the effects of stretching on multiple vertical jumps. Most previous studies were conducted using only “athletic” subjects. In this study we used subjects of “average” fitness level and therefore will be more applicable to the general population.

As a result of the study, coaches should have a better understanding of whether stretching is advantageous or detrimental to overall performance. This study will also help with understanding how long stretching effects last.

Delimitations

The study was delimited to

- 1) 20 (10 female and 10 male) Western Kentucky University Volleyball 101 students.
- 2) Subjects with lower extremity (lower body) injuries or past surgeries were not allowed.
- 3) Subjects that had no medical history.
- 4) Subjects were not involved in any type of stretching routine or class.
- 5) Subjects were requested to do their normal amount of activity throughout the study.

Limitations

The study was limited to

- 1) Volunteers.
- 2) Subjects' daily physical activities.
- 3) The type of activity classes in which the subjects were enrolled.

- 4) The effort that each subject was willing to put forward.
- 5) The honesty of each subject during the stretching routine.
- 6) The time of day each subject was able to perform the test.

Assumptions

The assumptions of the study were

- 1) Each subject knew and followed the rules of the study.
- 2) Each subject gave 100% during testing time.
- 3) Each subject was completely honest.
- 4) The stretching routine was valid.
- 5) The instruments used were valid and reliable.

Definition of Terms

- 1) Warm-up: A 10-20 minute time period before exercise that consisted of a light jog or cycle to increase heart rate, and a stretching routine.
- 2) Cool-down: A 5-10 minute time period to allow heart rate and blood pressure to return to normal, and a stretching routine.
- 3) Muscular soreness: A feeling of sensitivity or tightness within muscle from an exercise that was recently performed.
- 4) Vertical Jump: A jump performed straight upward to measure the height a person is capable of jumping.
- 5) Countermovement jumps: A vertical jump performed with a person standing vertically, followed by knee and hip flexion, followed by extension to launch them vertically.

- 6) Drop Jumps: A vertical jump performance when a person drops from a certain height and then proceeds to jump as high as possible.
- 7) Delayed onset muscle soreness: Muscle soreness that occurred 24-48 hours after physical exertion.
- 8) Range of motion (ROM): The amount of movement that a joint is able to move through.
- 9) Static stretching: A slow movement to the end of the ROM and then held for a period of 30s or more.
- 10) Proprioceptive Neuromuscular Facilitation (PNF): Static stretching with a partner to develop tension without shortening the muscle.

Chapter Two

Review of Literature

Numerous studies have been performed on the various aspects of stretching. A gap in the knowledge is how long stretching affects performance and what types of performance aspects researchers actually look at. Stretching has consistently been a part of warm-up and cool-down for all exercise and sports for years. New research findings may necessitate changing their views on stretching and when it is appropriate. There are many different stretching protocols that may affect performance. For example stretch-shortening cycle (SSC), soreness, strength, range of motion, muscle fatigue, and different sport specific movements all have an affect on performance. Any of these may have a negative, positive, or no effect on performance.

Comprehension of the Stretch Shortening Cycle (SSC) requires an understanding of muscle contraction. We will start with muscle contraction at the sarcomere. Within the sarcomere there are thin (actin) and thick (myosin) filaments. These two proteins are automatically attracted to each other. The contraction of a muscle occurs when the thick and thin filaments slide and overlap each other. This overlapping occurs when myosin attaches to actin and pulls on it. The place where actin and myosin combine is called a crossbridge. Once this crossbridge is formed the myosin heads bend and pull on the actin, the myosin head releases the actin. To make this process occurs you must have an energy source of adenosine triphosphate (ATP). ATP is required for both contraction and

relaxation. The use of ATP during contraction is used during the sliding filament stage, which is the bending of the myosin head bending. The relaxation stage needs ATP during the separation from the actin and also the breaking of the crossbridge. The reason why actin is not constantly bound to myosin is that there is another protein that is attracted to actin, which is troponin. Troponin is attracted to three different proteins: actin, tropomyosin complex, and calcium. Actin sites are usually not exposed because the long protein of the tropomyosin complex is being held in place by troponin. Once troponin releases so the tropomyosin complex can bind to calcium, then tropomyosin complex releases and allows myosin to bind to actin, thus leading to muscle contraction. You must have calcium present to achieve muscle contraction. Calcium is released due to an electrical signal sent from the brain to the sarcoplasmic reticulum. The sarcoplasmic reticulum has a calcium pump, which pumps the calcium in and out to achieve contraction and relaxation (Baechle et al. 2000).

The SSC has been shown to work (Doan et al. 2002) but researchers are unsure of the mechanism. Recent research involves controversial issues such as time available for force production, reflexes, storage and reutilization of elastic energy, potentiation of contractile movement, and the length-tension relationship.

One possible explanation for performance change due to SSC is the amount of time available for force production. It is theorized that the more time muscles have to develop crossbridges, the more force they will produce. Muscle fiber type and time of excitation affects the amount of time it takes a muscle to reach maximal force. On average it may take between 300-500ms to reach 90% of maximal force (Ingen et al. 1997). This time varies with the type of muscle fiber. Muscle fibers are basically

classified as type I, type II A and type II B. Essentially there are slow and fast twitch fibers. Type I are the slow oxidative fibers and their characteristics are slow contraction time, high resistance to fatigue, used primarily for aerobic activity and low force production. Type II A are fast oxidative-glycolytic fibers and their characteristics are fast contraction, average resistance to fatigue, used primarily for long term anaerobic activity and have high force production. Finally, Type II B are fast twitch glycolytic fibers and their characteristics are: extremely fast contraction time, low resistance to fatigue, used for short term anaerobic activity and have extremely high force production. Each person has all muscle types but some have higher amounts of a particular type. Depending on what type of muscle fiber is dominant in a person, time may or may not prove beneficial. Type I muscle fibers will benefit from extended time to produce force more than type II A or type II B. Fast twitch muscle fibers work at a faster rate, so they do not need extra time to produce more force. Another point that may affect time to produce power is how fast the brain sends an electrical signal to start the actual contraction. If your central nervous system works at a faster pace extra time will not be needed but, if it does the opposite, the muscle will benefit from the extra time utilized during the countermovement. The question remains, is the amount of time for force production the reason why the SSC is beneficial? There is too little research to give a definite answer to the question of time in relation to the benefits of the SSC.

Another element of the SSC is that the countermovement triggers spinal reflexes as well as longer latency. Spinal reflexes are triggered during the countermovement and a longer latency helps increase the concentric phase of the movement. This effect was described in a study that examined spindle afferent discharge during the SSC (Trimble et

al. 2000). The researchers found that reflexes provide a synchronization of the neural drive. The action of the countermovement actually is thought to stimulate the concentric phase of the movement to supramaximal. This goes along with potentiation of contractile machinery. If the muscle fibers do not lengthen there is no trigger for the spinal reflexes. Therefore, the countermovement does not stimulate spinal reflexes or longer latency because the muscle fibers may not stretch at all. This lack of stretching was demonstrated in a study that involved volleyball players using the squat jump and the countermovement jump (Ingen et al. 1997). This study took EMG of the subjects' legs and found that enhancement does not occur in the countermovement jump. A study by Kubo et al. (2000) found that tendon structures make the dynamics of the muscle-tendon complex more efficient during the SSC. The researchers found that 42.5% of the total amount of work completed during plantar flexion was due to the tendon structures. The authors concluded that the stretch reflexes are necessary to linearize the stress-strain characteristics not to enlarge the range of high stiffness. There is too little information to decide whether spinal reflexes are the mechanism that helps with the benefits of the SSC.

Elastic energy is another aspect that may be involved is the SSC. It has been demonstrated that elastic energy does exist but scientists are not sure whether it plays a role in the SSC (Finni et al. 2000). Elastic energy is stored by the muscle-tendon complex and later reutilized for force production during the concentric phase. The researchers speculated that high mechanical energy levels are abundantly provided by elastic structures (Minetti et al. 1997). In essence, during the countermovement the muscle is able to absorb more energy than usual. Then the muscle reutilizes this energy during the concentric phase, producing more force. A study that investigated elasticity of the

tendinous tissue found that the increased prestretch intensity did influence the amount of elastic energy that was used during the SSC (Ishikawa et al. 2004). This study only had 10 subjects, which may not be enough to confirm the findings. Some argue that this increase in elastic energy is due to the speed of the prestretch. A study done on the characteristics of the force-velocity relationship and muscle –tendon unit found that the increased speed during the countermovement enhanced mechanical output due to storage and recoil of elastic energy (Finni et al. 2003). Many argue that the increase in this force is not due to elastic energy, but rather the time the muscle has to build force. Storage of elastic energy is not increased due to the countermovement, but rather increased due to the amount of force at the start of the concentric phase. It is shown that the more time the muscle has to build, the more force it will produce. Therefore, it is obvious that if there is a countermovement the muscle has time to build more force and more elastic energy is stored due to the force produced by time. One study investigated the elasticity of the tendon structures of the lower limbs of sprinters compared to a control group (Kubo et al. 2000). This study concluded that there was no difference between the two groups. This particular study was low on subject numbers and trying to find a small difference between the groups is hard with small subject numbers. Another study performed found that the ankle plantar flexors show a production and storage of energy in the musculotendon elastic structures for later use (Neptune et al. 2004). This study did not provide information on their subjects, but did have a good protocol. There is much controversy on elastic energy and whether it affects the benefits of the SSC, which indicates a need for future studies.

Researchers have studied potentiation of the contractile machinery. Potentiation is the enhancement of maximum isometric force due to a countermovement. The contractile machinery is when myosin and actin bind to each other. It has been shown that force production increases following a countermovement. Researchers believe that the potentiation will enhance with the speed of stretch. A study performed on the force-velocity relationship showed that this increase in the speed of stretch increased potentiation (Finni et al. 2003). This increase in potentiation is because the myosin acts like a rubber band and when it is stretched to full potential and then released it will snap back into place quicker. This increase in potentiation leads to the contractile machinery also being enhanced, possibly due to strained crossbridges. The crossbridges are strained to the point where they detach and reattach quicker. A study performed on an active stretch during muscle contraction found that a potentiation effect does occur (Ettema et al. 1992). The issue with potentiation is whether it actually happens. When researchers study the SSC it is difficult to study in vivo (in action), so they do similar exercise to stimulate a SSC movement. The stimulation movements are much faster than in vivo. Some believe that muscle fibers do not stretch at all but remain the same or shorter. Therefore, the point of potentiation of the contractile machinery would have nothing to do with the SSC benefits. There is not enough information to make a decision whether potentiation of the contractile machinery is the reason for the benefits of the SSC.

Another factor that may affect the SSC is the length-tension relationship. The basis of the length-tension relationship is that tension generation in muscle is a direct function of the overlap between the actin and myosin filaments (Lieber 1999). The length-tension relationship is related to the SSC because when a muscle is isometrically

contracted it is only using the actin and myosin filaments that are overlapping; therefore, not all myosin heads are being used during isometric contraction. The lack of use is possible due to slack within the myosin filament. The lack of use is also true for the concentric contractions. Myosin filaments are different lengths and at certain lengths some of the myosin filaments are not being utilized. Longer myosin filaments are unable to attach to actin filaments during concentric contraction because of the slack within the myosin. Scientists say that if there is a countermovement first then the slack in the longer myosin filaments is removed and these longer myosin filaments are able to interact with the contraction and go through the grab, pull and release process. A muscle contraction does not use all of the myosin heads, but the more a muscle can use the more crossbridges formed and the more force produced. A study performed supports the idea of slack in myosin, it was performed on cats and demonstrated with length changes there was a rise in tension and more crossbridges were formed (Whitehead et al. 2001). The length-tension is the longer you make a muscle the more tension within that muscle and more crossbridges are formed and that results in more force produced. Overall, it has been shown that the SSC is beneficial, but it has not yet been shown why. These are some recent topics amongst researchers that could possibly be the reason or combined with the each other be the reason why SSC is beneficial.

Delayed onset muscle soreness (DOMS) is another of the topics that researchers have studied. The question is whether stretching prevents DOMS or not. According to studies performed by Lund and Johansson (1998, 1999) stretching has no long-term effect on DOMS. Both studies revealed that soreness peaked at 48 hours, and subjects reported less pain immediately after stretching for a short period. The two studies tested

only female subjects and just a few of them (Lund et al 1998; Johansson et al 1999). DOMS could have a negative effect on a person's performance because the soreness could slow reaction time and slow foot speed.

Strength is helpful to performance. The stronger the person is the better they will perform. The question is whether stretching helps or hinders in building muscle strength. A recent study performed by Arnold et al. (2001) found that stretching inhibits muscle strength. He found that his subjects were becoming more flexible, but they decreased in their 1 RM. This decrease in strength shows that stretching hinders muscle strength, which in turn will likely hinder performance.

Another aspect that may affect performance is range of motion (ROM). In the past it had been well known that the more ROM the better the performance, but now that has been challenged. Studies show that stretching does enhance ROM. For example, Reid et al. (2004) and Funk et al. (2004) both found that stretching does enhance ROM. Reid tested the average population and found that static stretching enhances ROM, whereas, Funk studied college athletes and found that proprioceptive neuromuscular facilitation stretching does enhance ROM. Yet, Funk found that static stretching did not enhance ROM for the college athletes. Elite groups, such as college athletes, need to do more than static stretching to increase ROM.

Injury prevention is also an aspect that may affect performance. Stretching has always been linked to injury prevention, but recent studies have questioned this. Some studies indicated that in some sports participants do not need to stretch because not only does it not prevent injury but also hinders their performance. In other sports it was found that there was a need for stretching to prevent injury. Bixler et al. (1992) found that in a

high-energy sport stretching should be used to avoid injury. The author stated that athletes in sports like football need to stretch to avoid injury because after stretching the muscle it is able to absorb more energy and, therefore, lessens the load on the muscle. This can potentially lead to injury prevention. On the other hand, Mechelen et al. (1993) found that in sports like jogging and swimming stretching may not be needed. He actually provides evidence that stretching may hinder athletic performance.

There have been studies performed on specific sports, many of the studies were performed on different types of jumps. Koch et al. (2003) studied the standing broad jump (SBJ). He did not find any difference between the stretching and the other groups. Hunter et al. (2002) performed a study on vertical jump (countermovement jump and drop jumps), and found that stretching alone did not have an effect on drop jumps but had a slight positive effect on countermovement jump. Hunter only tested male college athletes, which was supported by Funk et al. (2003) that static stretching does not affect “elite” athletes. A study by Knudson et al. (2004) found that stretching had no effect on tennis serve.

Within these studies there have not been studies on multiple jumps and the time period stretching effects last. Most of the studies also lack in stretching protocols. The researchers depend on subjects to do the stretching on their own. A number of the studies had small samples and thus suffer from poor power (Lund et al. 1998; Johansson et al. 1999; Reid et al. 2004; Funk et al. 2003; Arnold et al. 2001; and Hunter et al. 2002). Some only tested males or females and other only tested college athletes. Lund and Johansson also had a small number of subjects. Lund only used 7 female subjects and Johansson only used 10 female subjects.

Chapter Three

Methods and Procedure

Stretching may or may not have an effect on vertical jump, which is why this particular study is being conducted. The intent is to find out if stretching has an effect on vertical jump and if so, how long it lasts.

Subjects

Ten female and 10 male Western Kentucky students between 18 and 26 years of age were subjects in this study. The data was collected in Spring 2005. Subjects were not allowed to volunteer if they had any lower extremity injuries or surgeries. They also needed to be healthy and typical physically active college students. Their daily activity must be the same during the testing days. Subjects were not able to volunteer if they were involved in any type of stretching class or routine other than the stretching involved with the test. Each individual subject signed an informed consent form (Appendix A), which explained to them the procedure of the study, descriptions of the benefits, description of possible discomforts and/or risks, how they are able to withdraw at anytime with no consequences, and how they may inquire about the procedure at anytime.

Instruments

Data was collected using a Power Mat (probotics, Inc., Huntsville, Al.). The Power Mat calculated the height of each individual jump for each subject. This study used the 4-jump mode, which were 4 consecutive jumps on the Power Mat. The reaction time in seconds, the jump height in inches, and the leg power, which was a ratio of air

time and ground time were collected for each subject. The subjects tested during the morning (if possible) to control for excessive activity pre-testing.

Procedures

Each subject came into the lab for a pre-test. During the pre-test all methods for data collection were explained and a familiarization trial was performed. Once a pre-test was performed for familiarization each subject scheduled 3 appointments for their jump sessions (non, pre and between) on different mornings (48-72 hrs apart). This recovery time was used so the subjects would be able to recover fully before their next trial. Subjects were randomly assigned to the order for which they performed the trials. One was a control group (non-stretching), the second was a pre-stretching group and the third was a between-stretching group. Then each group was randomly assigned to an order in which they were to perform each test. The control group consisted of a rest period (420s), a test, another rest period (420s) and then the final test. The pre-stretching group consisted of a stretch routine (420s), a test, a rest period (420s) and then the final test. The between-stretching group consisted of a rest period (420s), a test, a stretching routine (420s) and then the final test. The stretching routine consisted of stretches for the gluteus maximus, hamstrings, quadriceps and triceps surae. Each muscle group was stretched for a total of 60 seconds. The stretches were done in two sets. Each stretch was held for 30 seconds. Subjects stretched the muscles in this order: gluteus maximus (30s), hamstrings (30s), quadriceps (30s), triceps surae (30s), stretching protocol was then repeated. The stretching time totaled 390 seconds. Between each set the subjects rested for 15 seconds, thus the stretching routine time totaled 420 seconds (7 minutes).

Gluteus Maximus Stretch: This stretch consisted of a supine knee flexion. The subjects laid on their back with legs straight out and brought one knee toward their chest. The subject held the stretch when a sensation was felt and then repeated for opposite leg (Baechle et al. 2000). See supine knee flexion in Appendix B (Baechle et al. 2000).

Hamstring Stretch: Consisted of a seated toe touch. Both legs straight out in front while sitting with their upper body vertical and then the subjects were directed to lean forward toward their knees (arms reaching toward toes) until they felt a sensation in their hamstrings. At that point they held the stretch for the designated time (Baechle et al. 2000). See seated toe touch in Appendix B (Baechle et al. 2000).

Quadriceps Stretch: Consisted of a side quadricep stretch. The subject lies on his or her side and places their left forearm flat on the floor and flexes right leg toward their back holding it with their right arm at the ankle. Once a sensation was felt in their quadricep the stretch was held for the designated time (Baechle et al. 2000). See side quadricep stretch in Appendix C (Baechle et al. 2000).

Tricep Surae: Consisted of the step stretch. Subject placed the ball of their foot on a step 3 to 4 inches off the ground and with a straight leg lowered the heel toward the ground and repeats with opposite leg (Baechle et al. 2000). The step stretch is pictured in Appendix C (Baechle et al. 2000).

Design and Analysis

Statistical analysis was performed using repeated measures ANOVA (SPSS 11.0). Bonferroni correction for multiple comparisons was utilized when significant main effects were detected. Statistical differences were considered significant at $p \leq 0.05$.

Research Design:

I	II	III
Control Group (non-stretching)	Pre-stretching Group	Between-stretching Group

Pilot Study

A pilot study was conducted to test the reliability, validity and the data collection procedures. Six subjects were involved in the pilot study and each individual was randomly assigned to a group and order as described in the study protocol. Each subject performed the same procedure and protocol.

Chapter Four

Results

Table 1 lists the descriptive statistics of the sampled population. Statistical analysis was performed using repeated measures ANOVA. Bonferroni was used to correct for multiple comparisons. Figure 1 shows the comparison of each individual group (none, pre and between) reaction time (rt) 1 versus rt 2. There was no difference in the non-stretching group ($p = 0.639$) or the between-stretching group ($p = 0.860$). There was a difference found in the pre-stretching group ($p = 0.035$). Figure 2 depicts the comparison of each individual group's leg power (lp) 1 versus lp 2. There was no difference found in the non-stretching group ($p = 0.515$), the between-stretching group ($p = 0.571$), or the pre-stretching-group ($p = 0.053$). Figure 3 displays the comparison of each individual groups jump height (jht) 1 versus jht 2. There was no significant difference in the none-stretching group ($p = 0.085$) or the pre-stretching group ($p = 0.294$). There was a significant difference found in the between-stretching group ($p = 0.004$).

Non-stretching rt jump 1 versus pre-stretching rt jump1, was also compared and no difference was found ($p = 0.802$). Non-stretching rt jump 1 versus between-stretching jump 1 there were no significant findings ($p = 1.00$). There were also no significant findings when comparing pre-stretching rt jump 1 versus between-stretching jump 1 ($p = 0.452$). The same comparisons were with rt jump 2 and there was no significant findings: none vs. pre ($p = 1.00$), non vs. between ($p = 0.519$), and pre vs. between ($p = 1.00$). This

comparison continued for lp jump 1: non vs. pre ($p = 1.00$), none vs. between ($p = 1.00$), and pre vs. between ($p = 1.00$). For leg power jump 2 there was no difference found: non vs. pre ($p = 1.00$), non vs. between ($p = 0.812$), and pre vs. between ($p = 0.662$). Jump height continued to be compared and there was no significant finding for jump 1 or jump 2. Jump 1: non vs. pre ($p = 1.00$), non vs. between ($p = 1.00$), and pre vs. between ($p = 1.00$). Jump 2: non vs. pre ($p = 1.00$), non vs. between ($p = 1.00$), and pre vs. between ($p = 1.00$).

No interactions were found for gender nor any other performance variable.

Chapter Five

Discussion

The purpose of this study was to examine whether stretching had an effect on vertical jump and, if so, how long the effect lasts. A repeated measures ANOVA was used to detect statistical differences. There was a difference comparing reaction time (rt) 1 versus reaction (rt) 2 in the pre-stretching group ($p = .035$), but no other group within rt. There was a p value extremely close to being significant within leg power (lp) 1 versus leg power (lp) 2 in the non-stretching group ($p = .053$). This was only .003 away from being significant, but no significance was found in either of the other two groups. There was also a difference found when comparing jump height (jht) 1 versus jump height (jht) 2 in the between-stretching group ($p = .004$), but no other group within jht. When comparing the first jump of each group to each other there was no significant findings between any of them. There were also no interactions found for gender. The three main results found in this research were that stretching adversely affected rt, lp and jht.

Reaction time was affected when jump one and jump two were compared in the pre-stretching group ($p = 0.035$). The stretching protocol had a negative effect on the subjects' reaction times, which could be due to speed of the stretch. During the study, a countermovement was not allowed and ultimately was not a quick stretch prior to the subjects' jumps. The only stretch that occurred was the 7 minute stretching protocol. This protocol stretched the myosin heads out of the reach of the actin filament. Therefore there was a lack of overlap of myosin filament over actin filament for them to attach (Lieber

1999). Considering the stretch was not quick enough to have a positive effect on the subjects' reaction times (Finni et al 2003).

Leg power was affected when comparing jump one with jump two in the pre-stretching group ($p = 0.053$). This p-value was not a significant finding. Both rt and lp were adversely effected. The effects that occurred could be supported by the lack of overlap between actin and myosin (Lieber 1999). If there are myosin heads free then there is not going to be as strong of a muscle contraction and therefore lp would be hindered (Baechle et al. 2000). This study was supported by Arnold et al. (2001), who found that stretching inhibits muscle strength, as well as Mechelen et al. (1993), who found that stretching hinders athletic performance.

Jump height was affected when comparing jump one with jump two in the between-stretching group ($p = 0.004$). This difference was likely due to the warm-up effect. Jump height was not affected by the pre-stretching group because the subjects had a jump directly after the stretching and then another jump so they were warmed-up for the second jump, whereas, in the between-stretching group the subjects did not have a warm-up after the stretching protocol and had a lower jump height directly after the stretching protocol (Koch 2003).

Stretching was found to adversely affect reaction time, leg power and jump height. The effect varied in time, as reaction was effected after the first jump along with leg power and jump height was affected directly after stretching. None of these components (rt , lp and jht) were affected when compared between groups. When comparing genders there were no significant interactions. Future research should include a countermovement to see the effects of the SSC on vertical jump with a strong stretching

protocol compared to no countermovement. Warm-up is another component to investigate. Research could test a warm-up session prior to the stretching or stretching followed by a warm-up to see how that affects vertical jump.

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APPENDIX A

INFORMED CONSENT DOCUMENT

Project Title: Effects of Stretching on Vertical Jump

Investigator: Carisa L. Chavez

You are being asked to participate in a project conducted through Western Kentucky University. It is a requirement that you give your signed agreement to participate in this project.

The researcher will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have.

If you then decide to participate in the project, please sign on the last page of this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

Purpose of the study:

Requirements:

YOU SHOULD NOT PARTICIPATE IF YOU:

- 1 ARE TRYING TO CONCEIVE CHILDREN
- 2 - YOU ARE TAKING DRUGS (PRESCRIPTION OR OTHER)
- 3 FAMILY HISTORY OF HEART, VASCULAR, OR KIDNEY DISEASE.
- 4 – YOU HAVE ANY MUSCULAR OR SKELETAL PROBLEMS

The lab sessions will be completed on separate days, in a random order, and will be as follows:

Session 1

The subjects will perform a familiarization test and demographic data was collected during this session.

Session 2

The subject will rest for 7 minutes, perform a jump test, rest 7 minutes, and perform a final jump test.

Session 3

The subject will perform the stretching protocol, perform a jump test, rest for 7 minutes, and perform a final jump test.

Session 4

The subject will rest for 7 minutes, perform a jump test, perform the stretching protocol, and perform the final jump test.

Risks Due to Participation

Potential risks to your health and well being because of your participation include: 1) pulled muscles, 2) muscle fatigue, 3) cardiovascular injury (heart attack, stroke, and death), 4) all other possible risks associated with physical activity.

*The American College of Sport Medicine (2000) suggests the following regarding the potential for risk/injury as the result of participating in exercise tests:

Risk of Death during or immediately after	<0.01% (1 in 10,000)
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Risk of heart attack during or immediately after <0.04% (4 in 10,000)
 Risk of hospitalization during as a result of testing <0.2% (2 in 1,000)

*Because your health history and current lifestyle habits have been evaluated prior to your participation, and because of the moderate nature of the exercise in this study, your risk is likely lower than those described above.

Safety of Participation

We will take every precaution to ensure your safety. It is very important that you fully disclose anything that would increase your risk for exercise. IT IS IMPORTANT THAT YOU DO NOT CONSUME HEAVY FOODS APPROXIMATELY 3 HOURS PRIOR TO EACH LAB SESSION. DRINK PLENTY OF FLUIDS AND AVOID ALCOHOL FOR 24 HOURS BEFORE EACH SESSION. ALSO, YOU SHOULD REPORT TO THE LAB EACH TIME WELL-RESTED (NO STRENOUS EXERCISE FOR 24 HOURS PRIOR LAB SESSION). Also, do not 1) take medication of any kind; 2) consume caffeine the days when you are participating.

Benefits of Participation

Benefits to the study are – you will receive information on your vertical jump height, additional information on your weight and height and the effects of stretching on vertical jump.

Right to Withdraw

It is your right to withdraw from the study at any point in time with no penalty. Withdrawing from the study will not adversely affect you in any manner. REFUSAL TO PARTICIPATE IN THIS STUDY WILL HAVE NO EFFECT ON ANY FUTURE SERVICES YOU MAY BE ENTITLED TO FROM THE UNIVERSITY. You should also understand that the investigator might ask you to withdraw from the study.

Privacy

Any information collected about you will be completely confidential. Your participation in the study will not be recognized nor will any personal information about you be made public. Only the primary investigator will have access to any personal information throughout the study. Should data be presented it will only be presented as group data and individual results will NOT be reported.

Voluntary Consent

If you fully understand what will be asked of you (should you decide to participate), please read and sign the following statement:

I freely and voluntarily and without undue inducement or any element of force, fraud, or any form of coercion, consent to be a subject in this research project. I understand that my participation is strictly voluntary and that I am free to withdraw my consent and discontinue participation at any time without penalty or prejudice. I also understand that my confidentiality will be protected and that my name will not be associated with the study results. I have been given the right to ask and have answered any questions that I may have regarding this research. I also understand that any other questions that I may have regarding this research or any procedure may be addressed to Carisa Chavez Graduate Assistant in the Physical Education and Recreation Department (858) 735-7566. If you are uncomfortable contacting Carisa Chavez, you may contact Dr. John Mclester at 745-6042. I have read and understand the above.

Name (please print): _____

Signature: _____ Date: _____

Address: _____ Telephone #: _____

Witness: _____ Date: _____

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

Signature of Participant: _____ Date: _____

Witness: _____ Date: _____

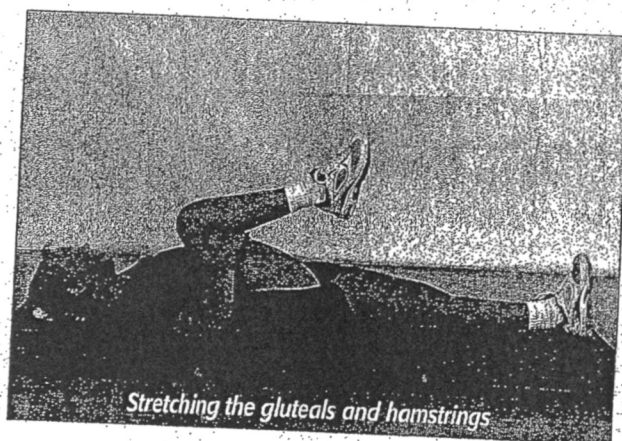
APPENDIX B

Supine Knee Flex

1. Lie on back with legs straight.
2. Flex right knee and hip, bringing thigh toward chest.
3. Place both hands behind thigh and continue to pull thigh toward chest (1).

MUSCLES AFFECTED

hip extensors (gluteus maximus and hamstrings)



Stretching the gluteals and hamstrings

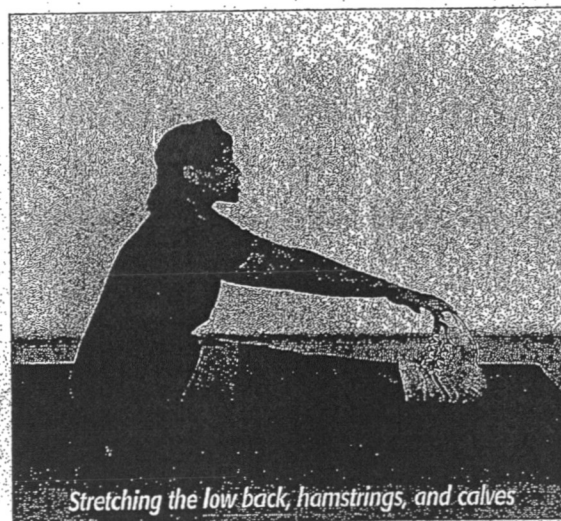
POSTERIOR OF THIGH

Sitting Toe Touch

1. Sit with the upper body nearly vertical and legs straight.
2. Lean forward using hip flexion and grasp toes with each hand. Slightly pull toes toward the upper body, and pull chest toward legs. If flexibility is limited, try to grasp the ankles (1).

MUSCLES AFFECTED

hamstrings, spinal erectors, and gastrocnemius



Stretching the low back, hamstrings, and calves

APPENDIX C

ANTERIOR OF THIGH AND HIP FLEXOR

Side Quadriceps Stretch

1. Lie on left side with both legs straight.
2. Place left forearm flat on floor and upper arm perpendicular to floor.
3. Place left forearm at 45° angle to torso.
4. Flex right leg (knee) with heel of right foot moving toward buttocks.
5. Grasp front of ankle with right hand and pull toward buttocks.

Note: The stretch occurs as a result of knee flexion and hip extension (1).

MUSCLES AFFECTED

quadriceps and iliopsoas



Stretching the quadriceps

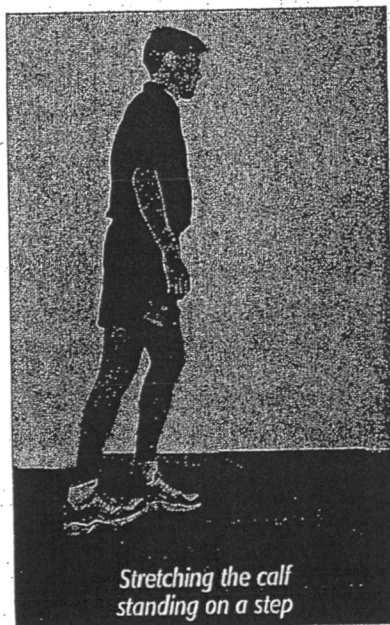
Step Stretch

1. Place ball of one foot on the edge of a step or board 3 to 4 in. (8-10 cm) high, with the other foot flat on the step.
2. With straight legs, lower the heel of the foot on the edge of the step as far as possible (see photo on left).
3. Repeat with other leg.

Note: To stretch the Achilles tendon, complete the same stretch with 10° of knee flexion (see middle and right photos).

MUSCLES AFFECTED

gastrocnemius and soleus; Achilles tendon



Stretching the calf standing on a step



Preparing to stretch the Achilles tendon by slightly bending the knee



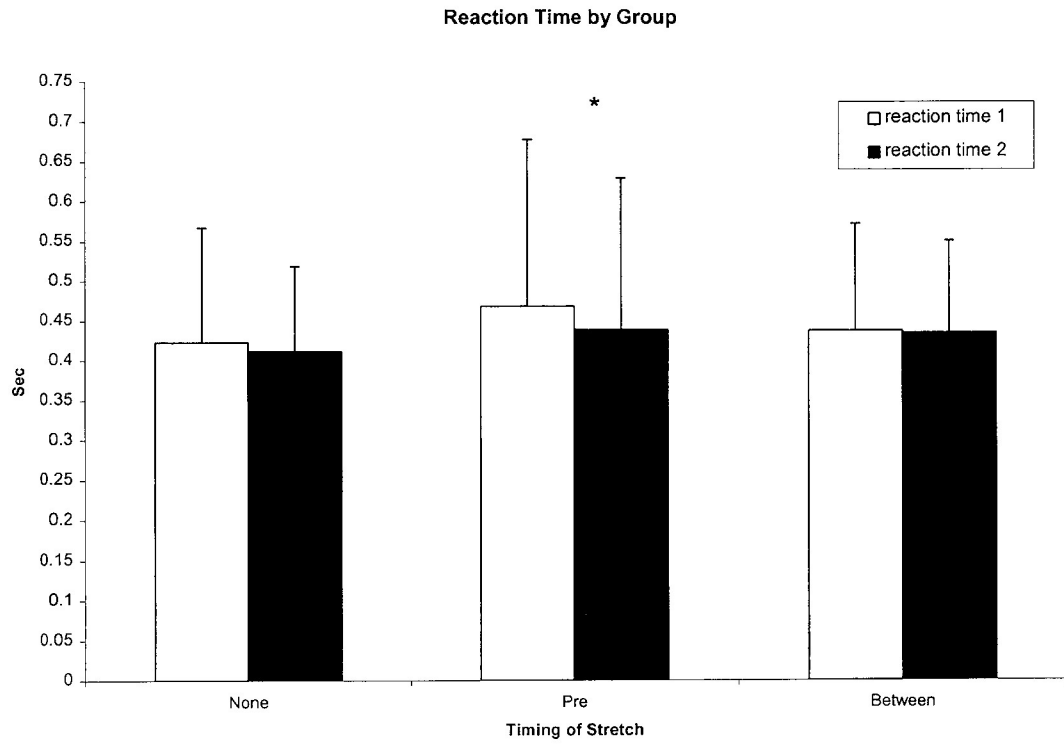
Stretching the Achilles tendon by lowering the heel

APPENDIX D

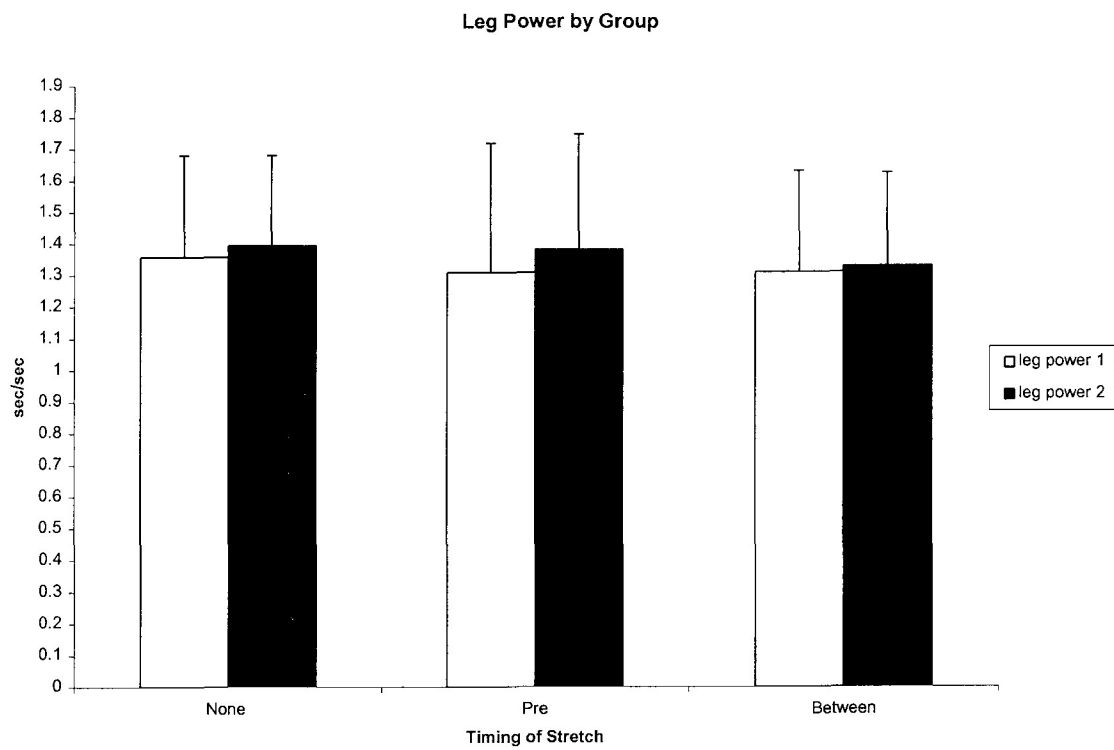
Table 1. Descriptive data of the population. Values are represented as mean \pm SD
(n = 20)

	Mean \pm SD
Age (yrs)	21.75 \pm 1.80278
Weight (kg)	147.95 \pm 28.44935
Height (cm)	172.086 \pm 11.19749
Body Fat %	16.09 \pm 5.13224
BMI	22.465 \pm 2.55966
Waist/Hip Ratio	.7603 \pm .05897

APPENDIX E



APPENDIX F



APPENDIX G

